BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 07064

SUBJECT: Skylab 1 Inflight Wind Constraints - Case 620

DATE: July 20, 1970

FROM: R. E. Hunter

ABSTRACT

Skylab 1 (SL-1) launch vehicle loads produced by in-flight winds are considerably more severe than those produced by the same wind environment on an Apollo/Saturn launch vehicle. These loads can be reduced by using a pitch and yaw plane wind biased trajectory.

Without a wind biased trajectory, SL-1 would be limited to a summer launch. Preliminary studies at MSFC have indicated that wind biasing can provide a launch probability for SL-1 in excess of .80 during the windiest month.

(NASA-CR-113126) SKYLAB 1 INFLIGHT WIND CONSTRAINTS, CASE 620 (Bellcomm, Inc.) 10 p

N79-72990

00/47 Unclas 11846

FF No. 602 CR-113126 (NASA CR OR TMX OR AD NUMBER)

(CODE)

(CATEGORY)

[redacted]

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MEMORANDUM FOR FILE

Skylab 1 (SL-1) aerodynamic and mass properties are such that launch vehicle loads produced by inflight winds are considerably more severe than those produced by the same wind environment on an Apollo/Saturn launch vehicle. This increase in SL-1 launch vehicle load, the areas being investigated to reduce SL-1 inflight wind loads, and the launch constraints created by these loads are discussed herein.

Differences in payload configuration between an Apollo vehicle and SL-1 are shown in Figure 1. The SL-1 payload shroud creates greater lateral aerodynamic forces at a given angle of attack, than the Apollo configuration. This increased lateral load on the forward end of the vehicle causes a forward shift in the aerodynamic center of pressure. The weight distribution for SL-1 is such that there is an aft shift in the center of mass compared to an Apollo vehicle. Figure 2 shows the difference in aerodynamic center of pressure and center of mass vs. flight time for SL-1 and a typical Apollo vehicle.[1,2] The forward shift in the aerodynamic center of pressure combined with the aft shift in the center of mass increases rigid body aerodynamic moments. These increased aerodynamic moments require greater thrust moments in order to maintain vehicle stability. The aft shift in the center of mass means that a given gimbal angle on SL-1 creates less control moment than the same gimbal angle on an Apollo vehicle.

The Apollo/Saturn design bending moment distribution at max $q\alpha$ is shown in Figure 3.[3,4,5] This bending moment distribution was calculated based on a synthetic wind profile is intended to be representative of a 95 percentile wind during the windiest month. In order to determine the Apollo design bending moment distribution this wind profile was assumed to be acting in the launch vehicle yaw plane, the direction that produces maximum bending moment.

The criteria used to determine Apollo design loads, if applied to the SL-1 launch, would effectively limit the program to summer launches. When the Apollo design wind profile is used to calculate SL-1 maximum bending moment distribution the resultant load, as shown in Figure 3, is 60% greater than the Apollo design bending moment. Extensive structural modification to the Saturn V launch vehicle would be required to survive this increased load. In order to reduce SL-1 launch vehicle maximum bending moment to the Apollo design moment, the maximum synthetic profile wind speed must be reduced from 75 m/s to 30 m/s. From Figure 5 the probability that a 30 m/s high altitude wind will be exceeded is greater than .5 during six months out of the year (November - April) and .85 during the months of January, February, and March.[7] It is important to realize that these calculations assume a severe wind profile (high shear and gust) and assume that the profile acts in the worst direction (yaw plane). Fortunately there are reasonable alternatives to this restriction short of a total rebuild of the Saturn V launch vehicle.

Considerable load relief can be achieved by taking advantage of the directional characteristic of high altitude winds. Prevailing altitude winds at KSC are from West to East; the high inclination launch azimuth (∿45°) for SL-1 increases the probability that high velocity winds will occur in the yaw plane. Thus in order to significantly reduce the maximum expected inflight wind loads for SL-1 it will be necessary to bias the trajectory in both the pitch and yaw plane. The trajectory for a winter launch would be determined such that minimum loads would be produced by the mean "directional wind profile" for that time of year. For example, if the wind during a particular month is persistently from the West, with a mean speed of 45 m/s, then the trajectory would be designed so that this mean wind profile would produce minimum vehicle loads.

Preliminary studies at MSFC have indicated that pitch and yaw plane wind biasing can provide a launch probability for SL-1 in excess of .80 during the windiest month. Calculations have been performed using actual KSC wind profiles and statistically determining the loads produced on the SL-1 vehicle using a wind biased trajectory. These results will be compared with loads produced by directional synthetic profiles.

Major changes to the Saturn V launch vehicle control system to include acceleration and/or velocity feedback for the SL-1 flight could further reduce launch loads. These areas are under investigation at MSFC but the current feeling is that wind biasing can provide sufficient load relief with no further changes necessary.

Present Skylab Program specifications require that SL-1 be able to survive a 75 m/s omnidirectional synthetic wind profile as defined in Reference 1. This criteria was established for development of Apollo/Saturn hardware. Use of the hardware in a new application necessitates a re-evaluation of both operational procedures and hardware capability, and the present specification is clearly unacceptable.

R. E. Hunter

2031-REH-ajj R. E. Hunter

REFERENCES

1. S&E-AERO-AA-69-M-34, Estimated Aerodynamic Characteristics of a Proposed Saturn V Dry Workshop Configuration, July 28, 1969.

2. D5-15509(F)-5, Saturn V Launch Vehicle Flight Dynamic Analysis, AS-505, The Boeing Company, April 15, 1969.

3. S&E-AERO-DF-49-69, Saturn V Workshop Vehicle Preliminary Rigid Body Control Analysis, September 2, 1969.

4. S&E-AERO-DF-64-69, Saturn V Workshop Vehicle, Preliminary Rigid Body Control Analysis Under Reduced Winds.

5. D5-15790, Apollo/Saturn V Space Vehicle Structural Integrity Assessment, AS-504, The Boeing Company, February 14, 1969.

6. NASA TM-53872, Terrestrial Environment (Climatic) Criteria Guidelines For Use in Space V icle Development, 1969 Revision, Glen E. Daniels, ed., September 8, 1969.

7. R-AERO-Y-118-66, Cape Kennedy Wind Component Statistics, 0 to 60 km. altitude, For all Flight Azimuths for Monthly and Annual Reference Periods, October 23, 1966.

FIGURE - 1

COMPARISON OF APOLLO AND SL-1 PAYLOAD CONFIGURATIONS

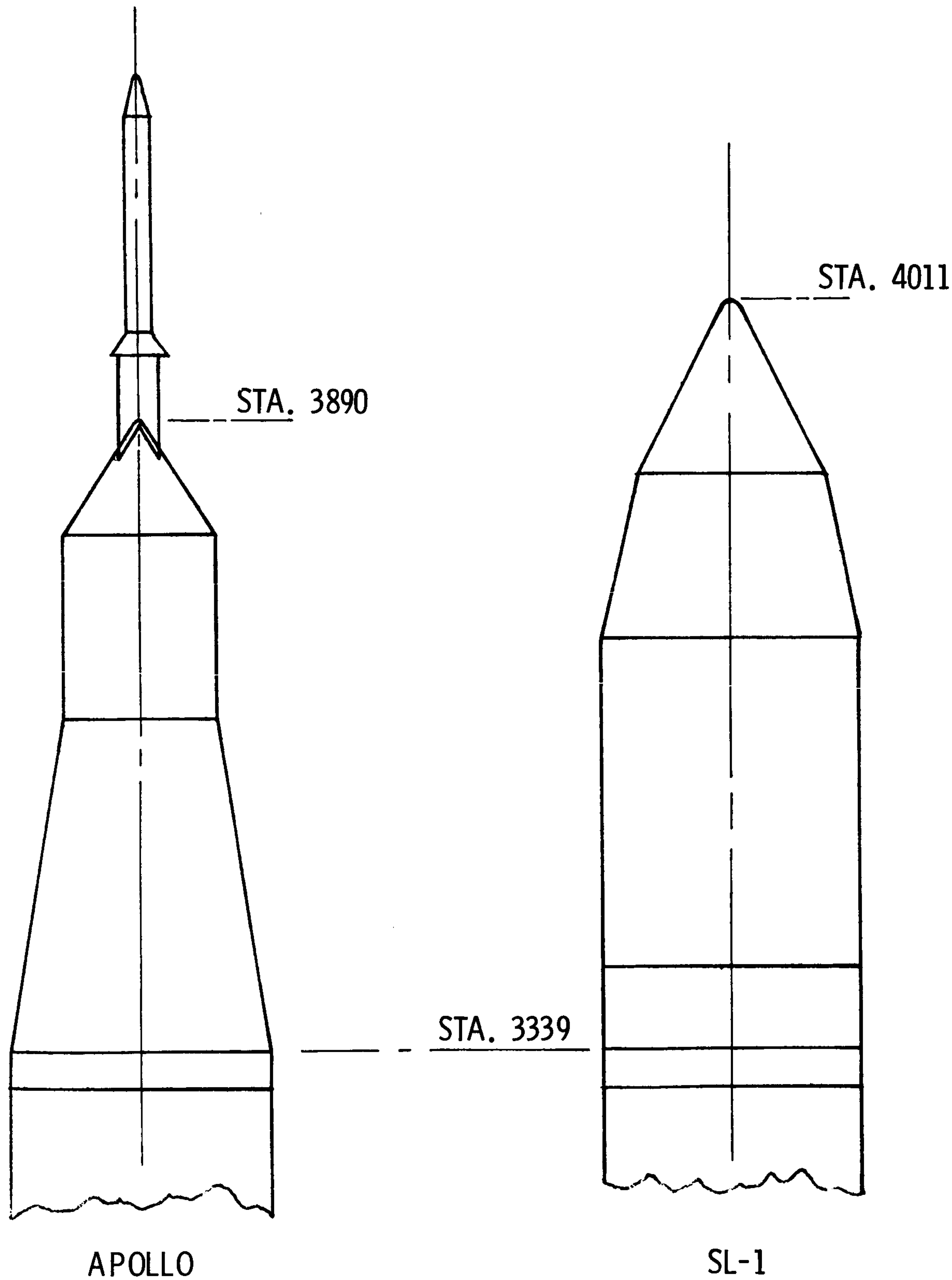


FIGURE - 2

COMPARISON OF SATURN/APOLLO AND SL-1
AERODYNAMIC CENTER OF PRESSURE
AND CENTER OF GRAVITY

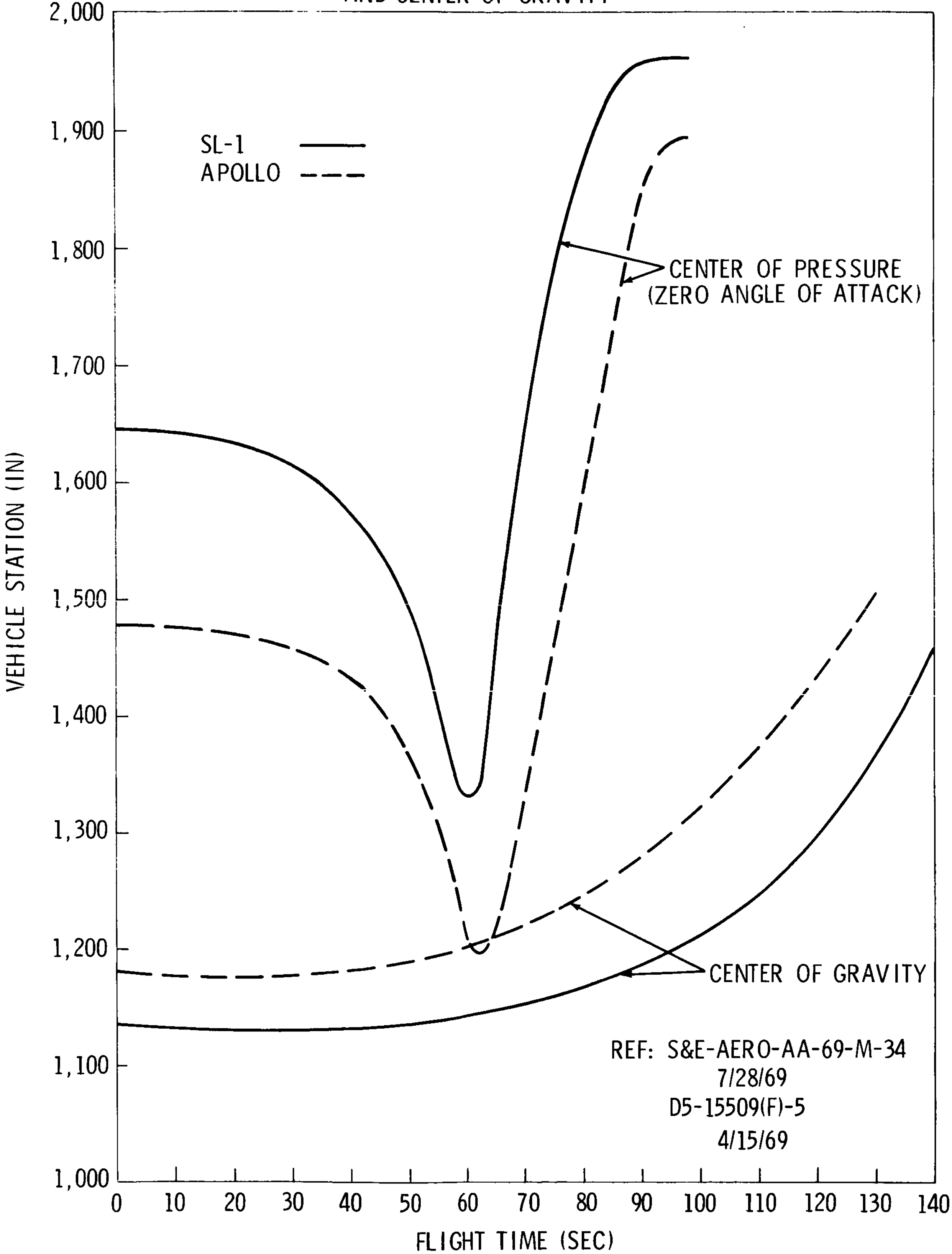


FIGURE - 3

SL-1 MAXIMUM RIGID BODY BENDING MOMENT

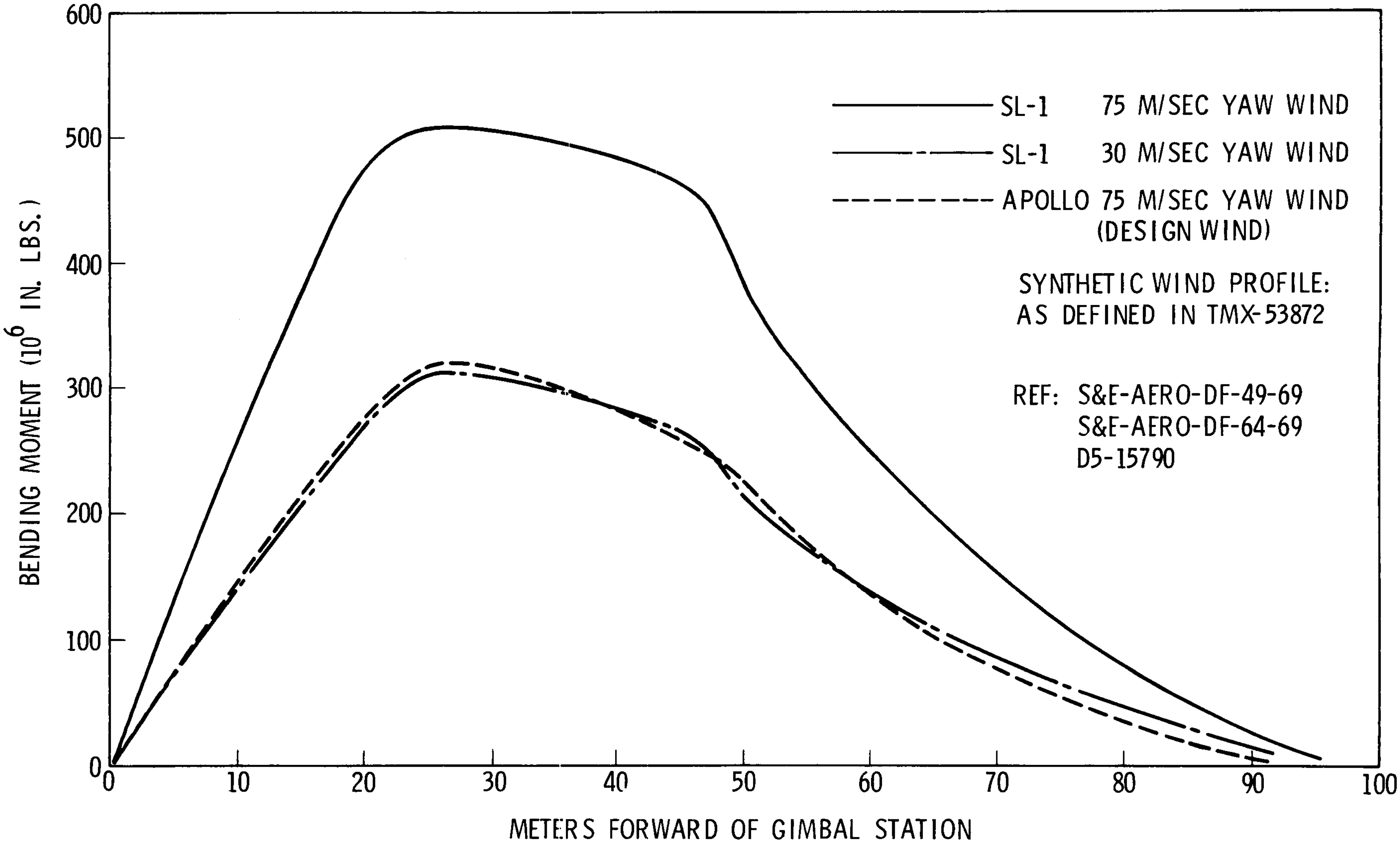


FIGURE - 4

APOLLO SYNTHETIC DESIGN WIND PROFILE

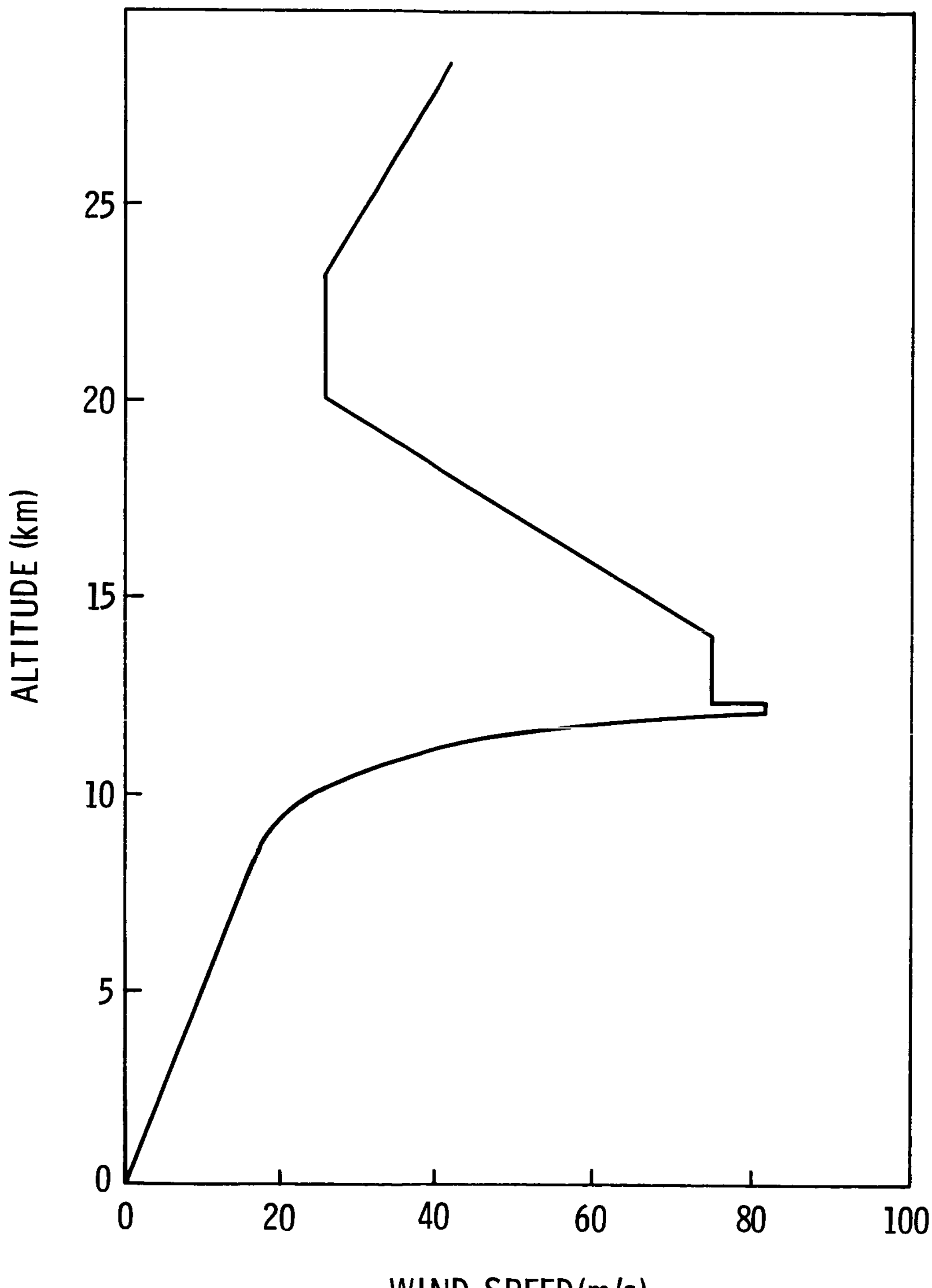
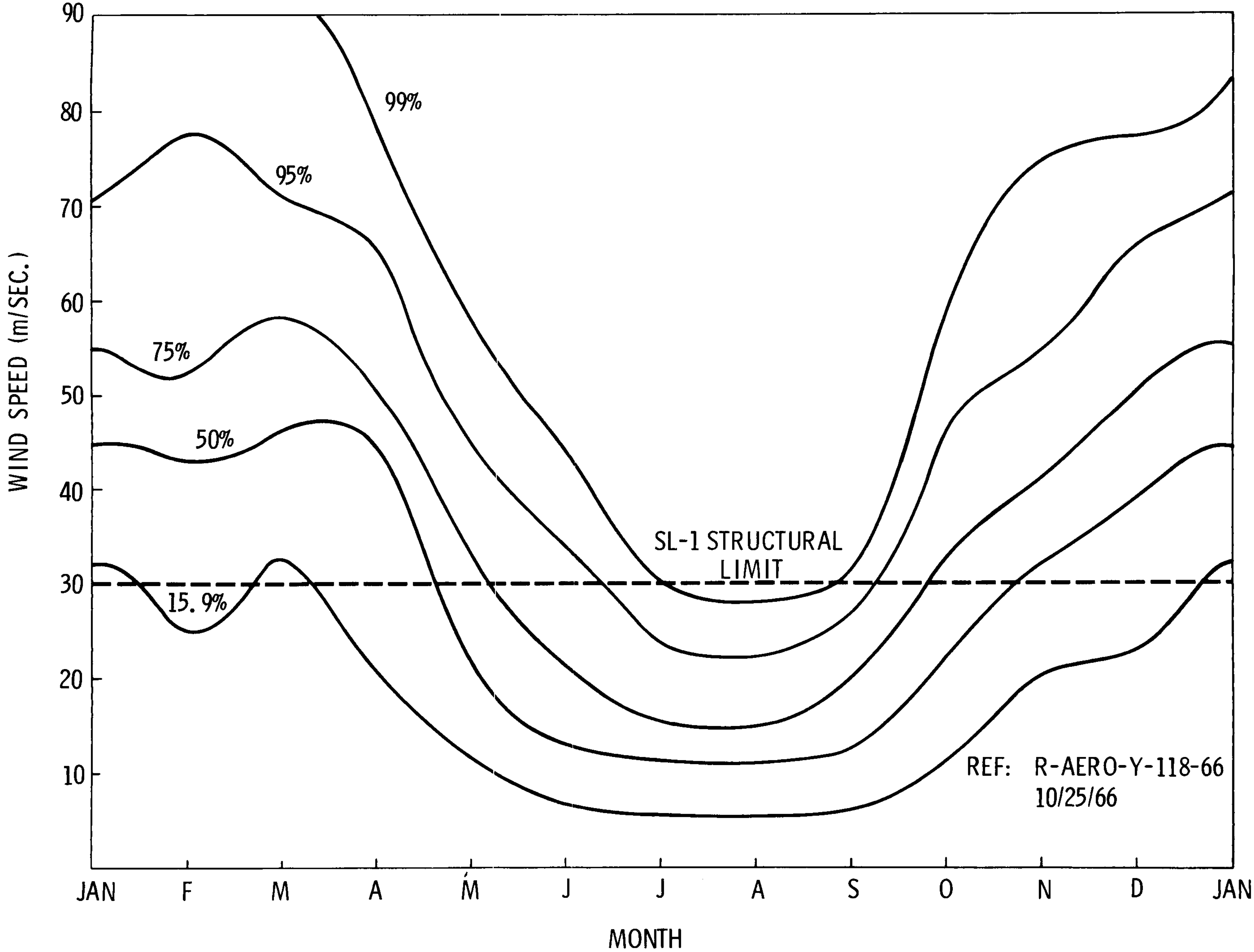


FIGURE - 5

KSC MONTHLY SCALAR WIND SPEED PERCENTILES



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